TD 345
.H94

WATER WORKS SYSTEMS

For SMALL TOWNS, CITIES, ETC.

Published
specially
for
city officials
who
are
contemplating
water works
construction

By RICHARD C. HUSTON

Member Western Society Engineers
Member Illinois Society Engineers and Surveyors
Vice-President American Public Works Association
Late Acting County Surveyor of Cook County, Chicago, Ill.

Chicago, Ill. —OFFICES— *Laurel, Miss.*

TD 345
.H94

LIBRARY of CONGRESS
Two Copies Received
MAY 3 1905
Copyright Entry
Sep 1. 1904
CLASS a XXc. No.
95625
COPY B.

Title and Original Contents Copyrighted
1904

PREFACE

The purpose of this little booklet is to emphasize the relationship that should exist between the City Father, the engineer and the contractor, in order to secure first-class systems of water works.

Its aim is to establish facts concerning this subject that will materially assist city officials in the purchase and maintenance of modern and economical plants.

Many of the tables and formulas in this booklet are not the work of the author, but are compiled from works of recognized standard merit. In some instances an average has been struck between the formulas of several recognized engineering authorities. Where they occur in the body of the reading-matter they will be found quoted. Some of the tables referring to quantity of material, cost of operating, etc., are compiled from the actual engineering work of the writer, and have never before been printed.

It has been the writer's object to use language readily understood by all, and for that reason, the almost total absence of technical engineering terms wil be noticed.

Richd. C. Huston,

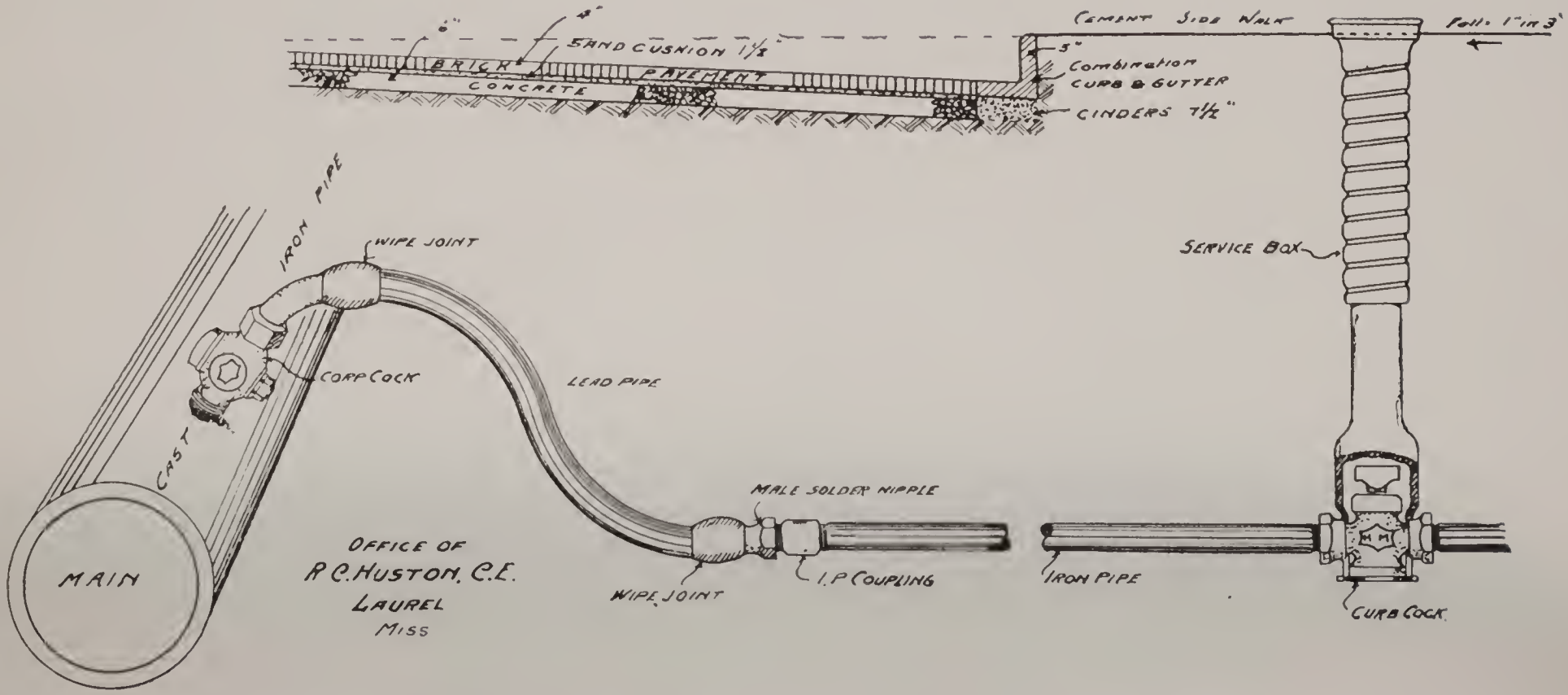
CONTENTS

PAGES

Air Compressors 12
American Public Works Association, Officers 35
" " " " Rules ..... 36 and 37
Appendix 27
Average Cost of Water Pipe 15
" Receipts of Water Companies 7
" Cost of Water Works 8
" Reduction in Insurance Rates 8
" Charge for Hydrant Rentals 7
" " " Taps 7
Capacity of Deep Well Pumps 12
Daily Allowance for Various Purposes 10
Distribution 13
Duplicate System 16
Electrical Units ..... 32 and 33
Electrolysis 20
Fire Protections 7
" Streams 11
Friction of Water in Elbows (table) 25
" " " " Pipes " 26
Gross Earnings of Water Works 8
Grade 20
Hydrants 19
" Connections (plate) 18
Hydraulic Grade Line 20
How to Pay for Water Works 20
Jute Packing (table) 15
Kind of Water 9
Lead (table) 15
Mensuration ..... 30 and 32
Mount Olive Pumping Station (plate) 17
" " " " description ..... 16 and 19
Number of Hydrants required 11
Operating Expenses 8
Power Station 16
Preface 3
Pressure, Temperature of Steam 27
Service, Water Connection (plate) 6
Source of Water Supply 11
Steam 28
Steam Heating 30
Steam Engine 29
Steel Tower and Tank 16
Stand Pipe 16
Tables of Velocities, Gallons discharged, Cost of Water Pipe, Friction, etc 15
" " Gallons discharged per minute through various sizes of Nozzles 24
" " Friction in Water Elbows 25
" " " " " Pipes 26
Units of Heat 34
Useful Information—Water 23
Valves 19
Water 28
Water Works 7
" " What Makes Possible a First-class 13
" " Cost 8
" " " of Operating 8
" " Earning 8
" Weight 28

MUELLERS

SERVICE WATER CONNECTION



Standard "TAP" or CONNECTION, showing Corporation Cock

WATER WORKS

About 60 per cent. of the water works plants in this country are owned and controlled by private parties, or corporations. Does this prove that water works is a good thing? Does it prove that it is a necessity? Let us consider for a moment the merits of good, pure and wholesome water for any community, large or small, and reason with ourselves, and see if we want to build and equip a first-class water works.

Water is required in every community for a great variety of uses:

First, the public uses are such as for cleaning streets, flushing sewers, for fountains, and last, but not least, for extinguishing fires. Second, the private uses are for drinking, washing, cooking, bathing; and in manufacturing towns for manufacturing purposes, water is indispensable.

The revenue from consumers is about as follows:

Fire protection to cities, towns, etc., furnished by private water works companies is paid for by hydrant rental, and usually runs from $30 to $60 per hydrant, $40 being about the average. It is customary for companies to furnish city water for fountains and public offices free of charge. For domestic purposes, the average charge throughout the country is $12.40 per tap per year. For manufacturing purposes, the water is generally delivered through meters and paid for at the rate of 5 cents to 25 cents per 1,000 gallons, according to the amount used. You will see from these charges, that financially speaking, a water works operated at about 60 to 65 per cent. of the gross receipts is a good investment. Does this not answer the question: Is water works a good thing?

Now, let us see what other benefit there is to be derived besides the general health of the community where a good, pure and adequate supply of water is to be had. An adequate water works will prevent excessive fires and thus cheapen the cost of insurance. The writer knows of many cases where towns of from 2,000 to 4,000 inhabitants have reduced the aggregate rate of insurance $1,500 to $3,500 per year respectively, or about 75 cents per capita. The total cost of water works will be about $8 to $10 per capita.

We have now estimated the cost of water works, let us see what returns can be expected. In a town of 5,000 people water works will cost, say $45,000. There will be approximately sixty fire hydrants. If the town owns and controls the works, it will save $40 per hydrant per year, or $2,400 per year. After the third year of the operation of water works we can safely estimate the number of taps as one to every fifteen people, or 333 taps or consumers in a town of 5,000 people. We can be conservative in estimating $1000 from mills, factories and manufacturing enterprises. A first-class system of water works can be operated at 63 per cent. of the gross receipts. When operated in connection with electric light plant this can be reduced.

RECAPITULATION OF GROSS EARNINGS

60 Hydrants at $40 each ..... per year		$2,400 00
333 Taps at $12.40 each ..... "		4,129 20
Manufacturing and Miscellaneous		1,000 00
Gross Receipts		$7,529 20

OPERATING EXPENSES

One Engineer at $83.33 per month	$1,000 00	
Two Firemen, $35 and $40; $75 per month	900 00	
600 Tons of Coal at $3 per ton	1,800 00	
Miscellaneous Expenses	500 00	
Total cost of operating	$4,200 00	
Fixed charges 45,000 in 5 per cent bonds	2,250 00	
Total Expenditures	$6,450 20	$6,450 20
Net Receipts		$1,079 20

The foregoing estimate is low, conservative, and the writer firmly believes the same to be below the average.

Now, let us add one more financial statement which I believe will convince the most skeptical that water works are a most safe, reliable and most needed improvement for every community. The taxpayers will save in their insurance premiums at least $3,000 per year. This item alone will more than pay for the interest on the bonds.

Now, reader, I hope I have interested you in the thought that we need and must have a system of water works. Let me now give you the most essential thoughts to be considered in procuring a first-class system of water works.

1st.—The kind of water.

2d.—The quantity of water.

3rd.—The source of supply.

4th.—The ways to convey it to the community.

In the answer to each of these thoughts, some of the most learned engineers have spent their entire earthly career in producing the best results. We have the results of their experiences as our guide, so let us profit by the pointers directed to us by the most competent authorities on the subject when contemplating the construction of any public improvement.

First, let us consider the kind of water.

A community requires pure water for some purposes, and those are specially for drinking and cooking. Pure water is not necessary for every purpose, such as for washing the streets, extinguishing fires, etc. However, practically speaking, it is desirable to get an ample supply of water of a certain quality sufficiently good for drinking. There are several ways of securing the supply, namely rivers, creeks, lakes, wells, and artesian wells, and to determine the best way is to procure a sample of each supply available and send the same to some competent and reliable chemist to analyze and report to your engineer the analysis of both quantative and

qualitive test, whose duty it will be to direct you to your source of supply. After determining the source of supply we must now direct our attention to the quantity. I will give here what I consider an ample daily allowance for the following purposes.

" Each person	5	gallons daily
Bath, average	25	" "
Horse	16	gallons daily
Two-wheel carriage	9	"
Four-wheel carriage	20	" } per application
Garden, one square yard	2½	" daily
Street Sprinkling		
Macadam—600 sq. yds	1	ton per application
Paved Block—400 sq. yds.	1	ton "
Manufacturing		
Varies 25 to 100 gallons per day."		

" On an average of 120 English towns the use of water daily for families is proven to be twenty-five gallons per head. The extremes are ten and fifty-six gallons." In America, this average is higher, about forty gallons per head. In large cities where large manufacturing plants are numerous, 150 gallons is not too much to estimate. However, in small cities, fifty gallons is a safe estimate to be delivered to the consumer for domestic purposes. This does not include the supply for fire protection, which is generally supplied from reservoirs holding about three to five hours' run—in case of fire supplying three to five hydrants of 250 gallons per minute for each hydrant. The pressure is kept constant by a fire pump (in absence of elevated tank and tower, or water storage tanks under air pressure with at least 200 feet head).

The following is the number of fire streams based upon the population:

Total Population	No. of 250 galls. streams available simultaneously *in addition to domestic service.*
1,000	2
3,000	3 to 5
5,000	4 to 6
10,000	5 to 11
20,000	7 to 14
40,000	12 to 20
60,000	16 to 24
100,000	20 to 32

To sustain a stream of 250 gallons per minute through 2 1-2 inch rubber hose, 100 feet in length and 1 1-4 inch nozzle, a pressure of forty-four pounds per square inch at the nozzle is required.

SOURCE OF SUPPLY

Having thus ascertained the quantity of water needed, let us now determine and secure the source of supply. We have found it necessary to take samples of all water for analysis which appears to us as a sufficient supply, and which may be from a river, lake, creek or artesian well, all of which are supplied from the rain. Rain in its first state is not fit for a proper water supply. In the first place it is soft and is well aerated. Thus it is necessary to collect it on the ground in order to get it pure. The impurities of rain are completely removed by filteration through the soil. Rivers and lakes fed by rain, or in other words, acting as collecting reservoirs are desirable, provided no adjacent, or nearby towns are disposing of their refuse, sewage, etc., into the stream, thus polluting it and rendering it unfit for public use, unless filtered or put through a chemical process, which is of course an expense but is worthy of due consideration. The next source of supply is the

artesian well. It is often thought that artesian wells always flow, but this is not the case. Water will always reach its level, and will not rise higher than its head.

The fact both abroad and in America has been thoroughly demonstrated that by means of properly constructed artesian wells varying from 150 feet to 3,000 feet in depth, water of the finest quality and temperature is obtained in great abundance, and is entirely free from surface contamination. There are two ways of securing your supply from deep wells, viz: The deep well pump and the air compressor. The deep well pump is used when the supply is limited, and the elevation of water is near the surface. I will give here the capacity of 4-inch, 6-inch, 8-inch and 10-inch wells as supplied with one of Cook's deep well pumps.

Inside Diameter of well	Gallons per day 24 hours
4 inches	34,732
6 "	106,596
8 "	197,216
10 "	318,124

The limited supply of a deep well, operated by deep well pump is because of the fact that the working barrel is limited in size, that is, an 8-inch well will take a 7 7-16 inch diameter working barrel with a stroke of twenty-four to thirty-six inches. The number of strokes varying from twenty to twenty-six per minute.

When it is necessary to have a large supply of water it will be advisable to install an air compressor, which supplies air to well by means of small pipes placed in the well, thus forcing the water to a receiving basin or reservoir, in large quantities, sometimes three to seven times that of a deep well pump. This system can be used for pumping any number of wells at the same time and located any distance away.

After determining the source of supply we must deliver the water to the consumer. I wish to state that there are many kinds

of water works as shown by the fact that under similar conditions water works at different localities vary in the cost of operation. The writer has made a study of these conditions, and has found many cases where the price of fuel and source of supply comparing favorably, but the operating expenses showed a large difference. This is due to the poor and indifferent design in many cases, causing excessive operating expense, while in the other case where operating expenses are minimum, the design is always first-class.

WHAT MAKES POSSIBLE A FIRST-CLASS WATER WORKS?

First.—A city or town with good and liberal-minded officials, who want, and will have the best that money can buy.

Second.—An engineer who has studied the conditions and will apply his understanding to the true principles of engineering to the best interests of his clients.

Third.—A contractor who will devote his entire time to fulfilling his contract in strict accordance with the specifications.

The business relations and all interests in the work of the city council, the engineer and the contractor should be identical, namely the securing of a first-class job, which will always be a monument to their combined ability.

DISTRIBUTION

Let us now convey the water to the community.

First.—We must lay out our distributing water mains from our pumping station, which should always be located near our supply of water, and if possible, near to our supply of fuel, that is, near a railroad, if we are dependent on coal supplied from neighboring cities.

The distribution should be designed so that the thickly settled part of the city can be supplied in duplicate from the pumping station.

These mains should be sufficiently large to afford an ample supply in case of fire with the least possible friction, that is, obviously water will flow with less loss of pressure through a large pipe than through a smaller one.

Water mains should be laid a little to one side of the center of the street, usually eight feet north and west of the center line, and mains should cross each other at street intersections at right angles, so in case of fire, hydrants can be supplied from both directions, which will double the supply.

No water main on business streets should be less than eight inch, and in dwelling section, not less than six inch, and when districts are thickly settled larger mains should be used. It is economy to lay sufficiently large mains in all cases—to meet future developments changed by subsequent erection of larger buildings, etc.

The size of the mains and pipe should be carefully guaged by a competent engineer to insure that too much head is not lost by friction, taking into consideration the supply needed for both domestic and fire purposes.

I give below the following table showing capacity of pipe of different diameters for various velocities of flow and loss of head by friction in feet for 1,000 feet of length, for new, clean pipe, taken as an average from M. D'Arcey, J. T. Fanning and F. C. Moore.

Diameter of Pipe in Inches	Velocity in Feet per Second	Gallons Discharge in 24 Hours	Average Cost per Lineal Foot of C. I. W. P. laid complete	Cost compared with 4-inch Pipe	With a Head of 150 feet, the length 1000 feet, the following Pipe will discharge "FANNING"	Friction per 1000 feet— Head required
4	3	154,080	$0 49	.....	.....	9. ft.
4	4	205,440	.....	.....	.....	17. ft.
6	3	378,432	61	1.24	40 cu. ft.	6.8 ft.
6	4	534,576	.....	.....	.....	12. ft.
8	3	676,512	82	1.46	80 cu. ft.	4.5 ft.
8	4	902,016	.....	.....	....	7.9 ft.
10	3	1,055,356	1 05	2.08	123 cu. ft.	4. ft.
10	4	1,413,048	.....	.....	.....	6.6 ft.
12	3	1,551,504	1 27	2.59	220 cu. ft.	..... .
12	4	2,128,672	.....	.....	.....	.....

In the above table the price of Cast Iron Water Pipe is estimated at $25.00 per ton.

By a careful study of the above table you can readily ascertain the size of main and comparative cost, and thus secure a rough estimate. You must bear in mind the excavation and surrounding conditions regulating the work must be considered by an expert before a complete estimate can be made.

The following is the number of pounds of lead required to make a joint on the sizes of pipe given below:

	Lead	Jute Packing
4 in.	4.7 lbs.	1-5 lbs.
6 "	6.6 "	1-5 "
8 "	9.1 "	¼ "
10 "	13.1 "	5-16 "
12 "	15.3 "	5-16 "
14 "	18.5 "	⅜ "
16 "	22.5 "	½ "
18 "	27.0 "	⅝ "
20 "	33.5 "	¾ "

Sometimes it is economy to erect a steel tower and tank, or standpipe on some elevated plot of ground near the central part of the town or city to secure the needed pressure for domestic service, and in case of fire to supply water until fire pumps can be put into operation. This is called the "duplicate system," and is desirable in many cases because of its economy in operation. You can fill the tank or standpipe in a few hours, and for the balance of the day leave sufficient supply without the aid of the pump. We will assume a tank of 100,000 gallons capacity erected on tower 100 feet to the bottom of tank; 1,000 feet of eight inch main, with three elbows, and using three hydrants simultaneously throwing 240 gallons per minute through 100 feet of 2 1-2 inch hose with 1 1-4 inch nozzle. We will be able to fight a fire for two hours and fifteen minutes. A duplex horizontal pump of 1,000,000 gallons capacity for twenty-four hours will fill the tank in two hours and fifteen minutes. This makes a very desirable system.

POWER STATION

When designing the power station, you must bear in mind that this part of the water works is the most important. We must have *first-class machinery, boiler,* etc. The insurance companies have recognized the necessity of this and they require all pumps, boilers, deep well pumps, or air compressors, wells, etc., to be made in duplicate before they will give any great reduction in rates of insurance.

Plate "A." is a plan of Mount Olive Pumping Station, showing the control of a duplicate system, by a series of valves.

"D. W." denotes a "Cook deep well pump," located over an 8-inch artesian well, having a capacity of more than 100,000 gallons per 24 hours. This pump will pump water from said well direct into reservoir (holding 50,000 gallons) by closing valve "C." If desired, this pump will force water into city mains and water tower by closing valves "B." and "E." and opening valves "C."

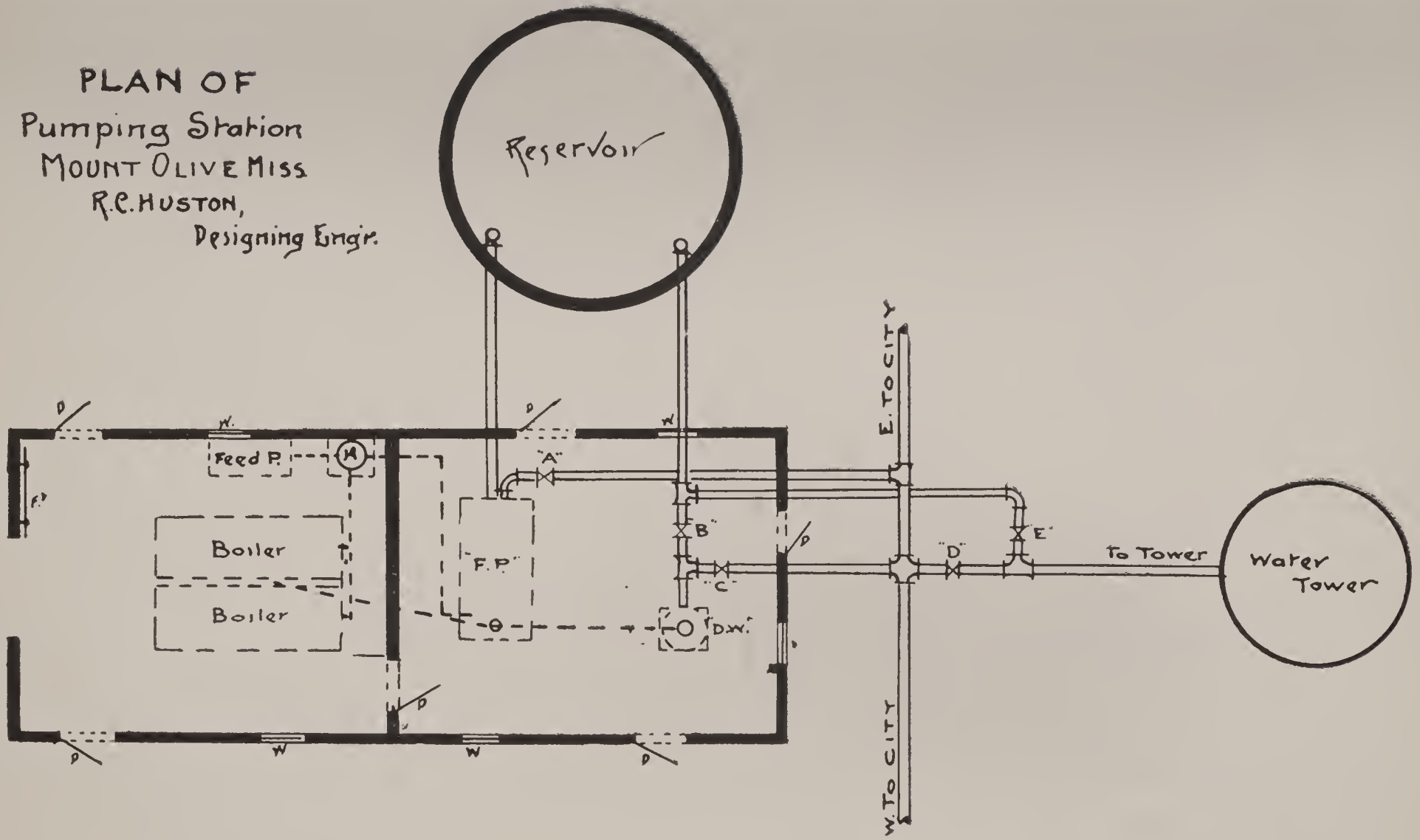
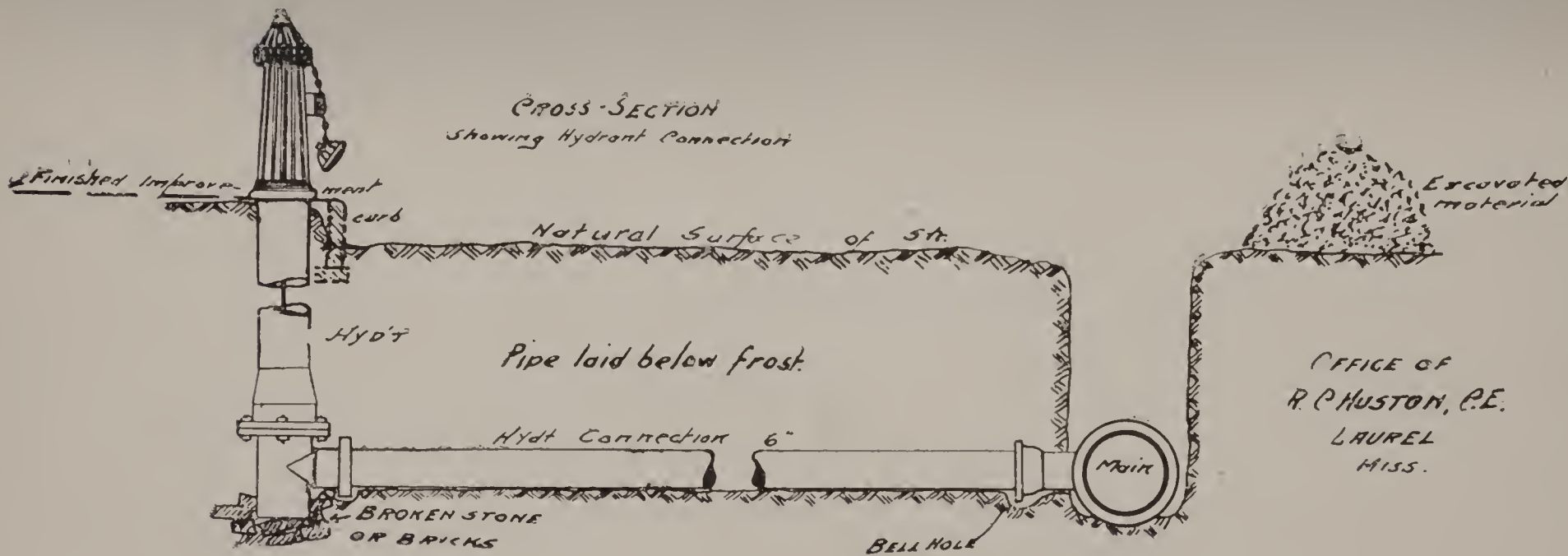

PLAN OF
Pumping Station
MOUNT OLIVE MISS.
R.C. HUSTON,
Designing Engr.
Reservoir
E. TO CITY
W. TO CITY
Feed P.
M
"A"
"B"
"C"
"D"
"E"
F.P.
Boiler
Boiler
"F.P."
D.W.
To Tower
Water Tower
D
W

PLATE "A"


CROSS-SECTION
Showing Hydrant Connection
Finished Improvement
curb
Natural Surface of St.
Excavated material
Hyd't
Pipe laid below frost
Hydt Connection 6"
Main
BROKEN STONE OR BRICKS
BELL HOLE
OFFICE OF
R. C. HUSTON, C.E.
LAUREL
MISS.

and "D." In case of fire, the horizontal duplex pump (Smith-Vaile make, capacity 500,000 gallons per 24 hours) "F. P." will take suction from reservoir, and by opening valve "A." and closing vales "C." and "D." will pump directly into city mains, sustaining a pressure of 150 pounds. And in case of emergency, the valves "C." and "D." being closed, the valve "E." opened, the water in tower will flow into reservoir, thus increasing the supply.

The town of Mount Olive has a population of 1,500. Cost of water works, $12.000. Constructed, 1904. W. C. Porter, contractor. R. C. Huston, designing and supervising engineer.

VALVES

Let us consider a few subjects with which we deal in the installation of a system of water works. The distribution of water mains should be well supplied with valves. In case of leaks or repairs in any section of the system this section can be shut off and repaired without the least interference of the rest of the mains, and again in case of a large fire, you can shut out other districts, thus enabling you to secure the output of your works in one or two sections at a time.

HYDRANTS

Fire hydrants should be placed at street corners and not more than 500 feet apart and connected with the largest main adjacent to the corner. They should be of standard design, and if cold weather is expected, be supplied with frost proof standpipe, and if funds will permit, hydrants should be installed with auxiliary valves.

Water hammer is a very dangerous thing and careful designing of valves and hydrants will help to minimize this trouble. The cause of shock in water pipe, or what is termed "Water Hammer," is the presence of air in the main, and by fast closing of a valve or hydrant against a pressure, which of course causes the rapid motion of the water to and fro in the main. The air thus imprisoned

makes a bubble which grows larger and larger as it recedes until it reaches a stopping place and causes a sudden shock. The simplest method of preventing "Water Hammer," according to Prof. Thurston, is to introduce devices compelling the slow opening and closing of valves.

HYDRAULIC GRADE LINE

In laying the water main the pipe should be laid at uniform depth and no point in the line of main should be above the hydraulic grade line. Hydraulic grade line, according to "Trautwine," is as follows: "In a straight tube of uniform diameter throughout, running full and discharging freely into the air, the hydraulic grade line is a straight line drawn from the discharge end to a point immediately over the entry end of the pipe and at a depth below the surface, equal to the entry and velocity head."

Electrolysis.—We sometimes hear of electrolysis affecting the cast iron water pipe. This occurs in cities having street railways, and is caused by fugitive currents of electricity which escape from the trolley, and other wires (unprovided with proper returns in shape of a good copper wire) and find the shortest path back to the negative pole of the machine sending out the current. If a line of pipe crosses this path at this place the electrolysis takes place and almost always where the current leaves the pipe.

GRADE

Another important feature in the construction of the mains is to lay the pipe a certain depth below an established grade for the proposed finished street surface. This prevents uncovering the pipes when streets are brought to grade by excavating surplus material. rial. Pipes should always be laid below the frost line.

Let us see how we can pay for water works.

In some cases cities desiring water works, advertise for plans and specifications and contract for a complete system. This usu-

ally invites a number of contractors submitting different designs at various prices, thus confusing the city authorities, unless they have competent advice to report on the plans, etc. After the city accepts a certain design on the condition the contractor is to construct the complete system ready for operation and sell the same to the city for a price to be fixed by a board of appraisers, consisting of one engineer appointed by the city and one engineer appointed by the contractor,, and if they fail to agree, the two engineers appoint the third engineer, who acts as referee and casts the deciding vote in case of a tie. After a price is fixed by the board, the city then votes "for" or "against" issuing bonds to pay for the works. If carried, the city advertises for purchasers of bonds to bid for this issue, the proceeds of which goes for the purchase of the works. While this is a good way to pay for a system in some respects, it is not desirable. In the first place, the contractor is compelled to carry the work to completion without any partial payment, which is always at the expense of the city at a later day.

Two other methods of meeting the cost of the system are to be considered. First.—Issuing bonds to pay for the works, charging same upon the whole city as a general taxation.

Second.—Dividing the benefit received from water works in two classes, viz: "Direct benefit" and "indirect benefit." The direct benefit is the pumping station, including pumps, boiler, fixtures, reservoir, and standpipe or tower and appurtenances necessary to furnish the general supply of water. The indirect benefit consists of the water main which benefits the property adjacent thereto.

The *direct* benefit is paid for by making the work a charge upon the whole municipality, raising the money by taxation or a bond issue. The indirect benefit is paid for by the issuing of special assessment bonds against the property adjacent to the proposed improvement. In this case the municipality is not liable for payment of the special assessment bonds, which reduces their value.

The preliminary steps to be taken by the city authorities is first to engage a competent civil engineer to make report and estimate of the proposed improvement. Mr. M. W. Baker, Ph. B., in works on "Sewerage and Sewage Purification" states, "The report of the engineer having been completed and submitted to the proper officials its adoption by them may be assumed. Sometimes the plan recommended has to be submitted to a popular vote, but more often when a vote is taken it is only indirectly upon the specific plans proposed, the real question being whether bonds shall or shall not be issued for the execution of the scheme. After the general report is adopted the next step is to select an engineer to prepare detailed plans and specifications preparatory to advertising for bids from contractors. Frequently the engineer who made the preliminary studies is engaged as designing engineer, and sometimes to supervise the construction as well. This course has the advantage of continuing the services of one more or less familiar with local conditions.

There is a vast amount of interesting and important matter which might be added to this booklet without exhausting the subject, but it is not the intention of the writer to make this a "technical guide," only a simple little book, which I hope will interest the "City Father" sufficiently to enable him to secure a first-class water works.

USEFUL INFORMATION—WATER

Doubling the diameter of a pipe increases its capacity four times. Friction of liquids in pipes increases as the square of the velocity.

The mean pressure of the atmosphere is usually estimated at 14.7 pounds per square inch, so that with a perfect vacuum it will sustain a column of mercury 29 9 inches or a column of water 33.9 feet high.

To find the pressure in pounds per square inch of a column of water, multiply the height of the column in feet by .434. Approximately, we say that every foot elevation is equal to one-half pounds pressure per square inch; this allows for ordinary friction.

To find the diameter of a pump cylinder to move a given quantity of water per minute (100 feet of piston being the standard of speed), divide the number of gallons by 4, then extract the square root, and the product will be the diameter in inches of the pump cylinder.

To find quantity of water elevated in one minute, running at 100 feet of piston speed per minute, square the diameter of the water cylinder in inches and multiply by 4. Example: Capacity of a five-inch cylinder is desired. The square of the diameter (5 inches) is 25, which, multiplied by 4, gives 100, the number of gallons per minute (approximately).

To find the horse-power necessary to elevate water to a given height, multiply the total weight of the water in pounds by the height in feet, and divide the product by 33,000 (an allowance of 25 per cent should be added for water friction, and a further allowance of 25 per cent for loss in steam cylinder).

The area of a Steam Piston, multiplied by the steam pressure, gives the total amount of pressure that an be exerted. *The area of the Water Piston*, multiplied by the pressure of water per square inch, gives the resistance. *A margin* must be made between the *power* and *resistance* to *move* the pistons at the required speed, say from 20 to 40 per cent, according to speed and other conditions.

To find capacity of Cylinder in gallons. Multiply the area in inches by the length of stroke in inches will give the total number of cubic inches; divide this amount by 231 (which is the cubical contents of a U. S. gallon in inches), and product is the capacity in gallons.

To find the number of gallons in a Tank, multiply the inside bottom diameter in inches by the inside top diameter in inches, then this product by 34; point off four figures and the result will be the average number of gallons to one inch in depth of the Tank.

The following table is arranged to show at a glance the equivalent pressure due to columns of water from 10 to 400 feet in height. Also more particularly to show the number of gallons of water delivered, and the height to which it will be projected through nozzles from one-quarter inch to two inches diameter.

Height of column in feet	Corresponding pressure in lbs. per square inch	DIAMETER OF NOZZLE IN INCHES																					
		¼		½		⅝		¾		1		1¼		1½		1¾		2	
		Height of Jet in feet	Gallons discharged per minute	Height of Jet in feet	Gallons discharged per minute	Height of Jet in feet	Gallons discharged per minute	Height of Jet in feet	Gallons discharged per minute	Height of Jet in feet	Gallons discharged per minute	Height of Jet in feet	Gallons discharged per minute	Height of Jet in feet	Gallons discharged per minute	Height of Jet in feet	Gallons discharged per minute	Height of Jet in feet	Gallons discharged per minute
10	4.3	9.37	3.6	9.7	14.5	9.7	22.7	9.8	32.8	9.8	58.2	9.9	91.	9.9	130.8	9.9	177.6	9.9	232.8
20	8.6	17.5	5.1	18.7	20.6	19.	32.2	19.2	46.2	19.4	82.3	19.5	128.4	19.6	184.8	19.6	252.	19.7	328.8
30	13.0	24.1	6.4	27.2	25.2	27.7	39.4	28.3	56.8	28.6	100.9	29.	157.2	29.1	226.8	29.2	309.6	29.3	403.2
40	17.3	30.0	7.3	35.0	29.6	36.	45.5	37.	65.5	37.5	116.5	38.	182.4	38.3	261.6	38.6	356.4	38.7	465.6
50	21.6	34.0	8.1	42.2	32.5	44.	50.9	45.	73.3	46.1	130.8	47.	204.	47.4	292.8	48.	408.	48.	520.8
60	26.	37.5	8.9	48.7	35.6	51.	55.7	52.	80.3	54.4	142.8	55.	223.2	56.2	320.4	57.	436.8	57.	571.2
70	30.3	39.	9.6	55.	38.5	58.	60.1	60.	86.8	62.4	154.8	61.	211.2	65.	346.8	66.	471.6	66.	616.8
80	34.6	39.4	10.3	60.	41.2	64.	61.3	67.	92.6	70.	161.4	72.	258.	73.	379.8	74.	505.2	75.	658.8
90	39.	40.	10.9	65.	43.7	70.	68.3	73.	98.1	77.	174.0	80.	272.4	82.	383.6	83.	535.2	84.	711.6
100	43.3	40.5	11.5	69.	46.1	75.	72.0	79.	103.7	84.	183.6	87.	288.	90.	415.2	91.	565.2	92.	738.
120	52.	....	13.	75.	50.4	84.	78.8	90.	113.5	97.	201.6	102.	315.6	105.	453.6	107.	626.4	109.	807.6
140	60.6	....	14.5	79.	54.5	91.	85.2	99.	122.4	109.	217.2	116.	340.8	120.	490.8	123.	668.4	125.	872.4
160	69.3	....	16.	80.	58.1	96.	90.8	106.	131.2	120.	232.9	128.	364.	133.	524.2	137.	713.5	140.	931.9
180	78.	....	17.5	....	61.6	99.	96.5	112.	139.1	129.	217.1	139.	373.	2141.	556.1	151.	756.9	155.	988.6
200	86.6	....	18.7	....	65.2	100.	101.8	116.	146.4	137.	260.4	150.	406.	8158.	588.	166.	798.	169.	1043.
220	95.1	....	....	....	....	....	106.7	119.	153.7	145.	273.3	159.	427.	1165.	615.	177.	837.1	182.	1087.6
240	104.	....	....	....	....	....	111.5	120.	160.6	150.	285.5	168.	446.	1180.	642.	189.	874.3	195.	1142.
260	112.6	....	....	....	....	....	116.	....	167.1	155.	297.1	175.	464.	2190.	668.5	200.	909.9	208.	1188.4
280	121.2	....	....	....	....	....	120.4	....	173.4	158.	308.3	182.	481.	8198.	693.8	210.	944.3	219.	1233.4
300	130.	....	....	....	....	....	124.8	....	178.8	160.	319.2	187.	498.	206.	717.6	220.	979.2	230.	1276.8
350	151.4	....	....	....	....	....	....	....	....	....	....	....	538.	5222.	775.5	241.	1055.5	255.	1278.7
400	173.0	....	....	....	....	....	....	....	....	....	....	200.	576.	233	829.4	257.	1128.9	275.	1474.5

The pressure or head of water is taken at the nozzle, no allowanee being made for friction in the pipe. In practical calculations to determine the height which water can be thrown the head consumed by the friction of the water in flowing from the pump to the nozzle must be considered.

FRICTION OF WATER IN ELBOWS

Pressure in Pounds per Square Inch to be Added for Each Elbow

Gallons per Minute Delivered	PIPE SIZES															
	¾	1	1¼	1½	2	2½	3	3½	4	5	6	7	8	9	10	12
5	.07	.027	.008	.005	.002	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10	.28	.094	.031	.018	.006	.003	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
15	.63	.212	.069	.04	.014	.005	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	1.12	.376	.123	.069	.025	.012	.005	.....	.....	.....	.....	.....	.....	.....	.....	.....
25	1.74	.585	.194	.108	.038	.02	.008	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	.....	.845	.278	.157	.055	.028	.011	.....	.....	.....	.....	.....	.....	.....	.....	.....
35	.....	1.15	.380	.215	.076	.037	.015	.009	.....	.....	.....	.....	.....	.....	.....	.....
40	.....	1.50	.495	.278	.098	.049	.02	.011	.007	.....	.....	.....	.....	.....	.....	.....
45	.....	1.90	.626	.352	.125	.062	.026	.015	.009	.....	.....	.....	.....	.....	.....	.....
50	.....	.....	.77	.43	.153	.08	.032	.017	.01	.....	.....	.....	.....	.....	.....	.....
60	.....	3.38	1.11	.62	.22	.112	.044	.026	.015	.006	.003	.....	.....	.....	.....	.....
70	.....	4.60	1.52	.860	.304	.148	.06	.035	.021	.009	.004	.002	.....	.....	.....	.....
75	.....	5.30	1.74	.98	.35	.172	.072	.04	.024	.01	.005	.003	.....	.....	.....	.....
80	.....	6.00	1.98	1.11	.392	.196	.08	.044	.027	.012	.005	.003	.....	.....	.....	.....
90	.....	7.60	2.50	1.41	.50	.248	.104	.06	.035	.014	.007	.004	.....	.....	.....	.....
100	.....	.....	3.08	1.72	.612	.32	.128	.068	.043	.017	.008	.005	.003	.002	.....	.....
125	.....	.....	.....	2.72	.970	.48	.20	.112	.067	.027	.013	.007	.004	.003	.002	.....
150	.....	.....	.....	3.92	1.39	.685	.286	.16	.096	.039	.019	.01	.006	.004	.003	.001
175	.....	.....	.....	5.32	1.90	.935	.390	.218	.132	.053	.026	.014	.009	.005	.004	.002
200	.....	.....	.....	6.88	2.44	.128	.512	.272	.172	.068	.032	.02	.011	.007	.005	.002
250	.....	.....	.....	.....	3.86	1.91	.80	.446	.263	.109	.045	.029	.017	.011	.007	.004
300	.....	.....	.....	.....	5.56	2.74	1.14	.64	.384	.156	.076	.042	.025	.016	.01	.005
350	.....	.....	.....	.....	.....	3.77	1.58	.88	.530	.215	.103	.057	.034	.022	.014	.007
400	.....	.....	.....	.....	.....	5.12	2.05	1.09	.688	.272	.128	.08	.044	.028	.018	.009
450	.....	.....	.....	.....	.....	6.20	2.58	1.45	.870	.352	.170	.094	.057	.035	.023	.011
500	.....	.....	.....	.....	.....	7.64	3.20	1.78	1.07	.436	.208	.116	.068	.044	.028	.016
750	.....	.....	.....	.....	.....	.....	.....	.....	2.42	.970	.470	.260	.156	.10	.063	.031
1000	.....	.....	.....	.....	.....	.....	.....	.....	4.28	1.74	.832	.464	.272	.176	.112	.064
1250	.....	.....	.....	.....	.....	.....	.....	.....	6.70	2.71	1.31	.728	.435	.276	.175	.086
1500	.....	.....	.....	.....	.....	.....	.....	.....	9.68	3.88	1.88	.84	.624	.40	.252	.124

Table is based on Weisbach's formula for very short bends, or with a radius equal to the radius of the pipe. To find "Fiction Head" in feet multiply figures by 2.3.

FRICTION OF WATER IN PIPES

Pressure in Pounds per Square Inch to be Added for Each 100 feet of Clean Iron Pipe

Gallons per Minute Delivered	PIPE SIZES															
	¾	1	1¼	1½	2	2½	3	3½	4	5	6	7	8	9	10	12
5	3.3	.84	.31	.12	.04	.02	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10	13.0	3.16	1.05	.47	.12	.04	.02	.....	.....	.....	.....	.....	.....	.....	.....	.....
15	28.7	6.98	2.38	.97	.25	.08	.04	02	.....	.....	.....	.....	.....	.....	.....	.....
20	50.4	12 3	4 07	1.66	.42	.14	.06	.03	.....	.....	.....	.....	.....	.....	.....	.....
25	78.0	19.0	6.40	2.62	.62	.21	.10	.04	.02	.....	.....	.....	.....	.....	.....	.....
30	.....	27 5	9.15	3.75	.91	.30	.13	.06	.03	.....	.....	.....	.....	.....	.....	.....
35	.....	37.0	12.4	5.05	1.22	.40	.17	09	.05	.02	.....	.....	.....	.....	.....	.....
40	.....	48.0	16.1	6.52	1 60	.50	.23	.11	.06	.02	.....	.....	.....	.....	.....	.....
45	.....	.....	20.2	8.15	1.99	.66	.28	14	.07	.03	.....	.....	.....	.....	.....	.....
50	.....	.....	24.9	10.0	2.44	81	.35	.17	.09	.04	.....	.....	.....	.....	.....	.....
60	.....	.....	36 0	14.0	3.50	1.17	.50	.24	.13	.05	.02	.....	.....	.....	.....	.....
70	.....	.....	48.0	20 0	4.80	1.50	.60	.38	.19	.07	.03	.....	.....	.....	.....	.....
75	.....	.....	56.1	22.4	5.32	1.80	.74	.....	.....	.....	.....	.....	.....	.....	.....	.....
80	.....	.....	64.0	25.0	6.30	2.00	.90	.41	.23	.08	.03	.....	.....	.....	.....	.....
90	.....	.....	80.0	32.0	7.80	2 58	1 10	.54	26	.09	.04	.....	.....	.....	.....	.....
100	.....	.....	.....	39 0	9.46	3.20	1 31	.64	.33	.12	.05	.02	.....	.....	.....	.....
125	.....	.....	.....	.....	14.9	4 89	1 99	.96	.49	.17	.07	.03	.....	.....	.....	.....
150	.....	.....	.....	.....	21 2	7.00	2 85	1.35	.69	25	.10	.04	.....	.....	.....	.....
175	.....	.....	.....	.....	28.1	9 46	3.85	1 82	.93	.31	.13	.05	.....	.....	.....	.....
200	.....	.....	.....	.....	37.5	12.47	5.02	2.38	1.22	42	.17	.07	.....	.....	.....	.....
250	.....	.....	.....	.....	.....	19.66	7.76	3.70	1.89	.65	.26	.12	.07	.04	.03	.01
300	.....	.....	.....	.....	.....	28.06	11.2	5 04	2.66	.93	.37	.17	.09	.05	.04	.....
350	.....	.....	.....	.....	.....	.....	15.2	7.10	3.65	1.26	.50	.23	.12	.07	.05	.02
400	.....	.....	.....	.....	.....	.....	19.5	9.25	4.73	1.61	.65	.30	.16	.09	.06	.....
450	.....	.....	.....	.....	.....	.....	25.0	11.70	6 01	2.00	.81	.37	.20	.11	.07	.03
500	.....	.....	.....	.....	.....	.....	30.8	14.5	7.43	2.40	.96	.45	.25	.14	.09	.04
750	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2.21	1.03	.53	.30	.18	.08
1000	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3.88	1.80	.94	.53	.32	.13
1250	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	6.00	2.85	1.46	.82	.49	.20
1500	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	8.60	4.08	2.09	1.17	.70	.29

Table is based on Ellis' and Howland's Experiments. To find "Friction Head" in feet multiply figures by 2.3

APPENDIX

These are practical figures, copied from reliable authorities

Ice nearly frozen	weighs	57.2	pounds
Temp. 40°	"	62.38	"
Salt Water	"	64.3	"

To ascertain how high water can be raised by vacuum:
Take elevation of Barometer and multiply it by (after being reduced to 32° Fah.) 1.333 = Head in feet.

Composition of Water:

Oxygen	8 parts
Hydrogen	1 part

Imperial Gallon = 276½ cubic inches = 6¼ gallons to 1 cubic foot. 1 gallon = 10 pounds.

United States Gallon = 231 cubic inches = 7½ gallons = 1 cubic foot (approximately) 1 gallon = 8.33 pounds.

PRESSURE, TEMPERATURE OF STEAM

From Atmospheric Pressure to 140 pounds per Square Inch.

Atmos. Pres.	212.8	12	245.5	34	281.9	90	335.8
1	216.2	14	249.6	40	289.3	95	339.2
2	219.6	16	253.6	45	295.5	100	342.7
3	222.7	18	257.3	50	301.3	105	345.8
4	225.6	20	260.9	55	306.4	110	349.1
5	228.5	22	264.3	60	311.2	115	852.1
6	231.2	24	267.5	65	315.8	120	355.
7	233.8	26	270.6	70	320.1	125	357.9
8	236.3	28	273.6	75	324.3	130	360.6
9	238.7	30	276.4	80	328.2	135	363.4
10	241.	32	279.2	85	332.	140	366.

A cubic inch of water, evaporated under ordinary atmospheric presure, is converted into 1,700 cubic inches, or, in round numbers, 1 cubic foot, and gives a mechanical force equal to raising 2,200 pounds one foot high.

STEAM

27,222 cubic feet of steam weigh one pound; 13,817 cubic feet of air weigh one pound.

The best designed boilers, well set with good draft, and skilful firing, will evaporate from 7 to 10 pounds of water per pound of first-class coal.

In calculating horse-power of Tubular or Flue boilers, consider 15 square feet of heating surface equivalent to one *nominal* horse-power.

On one square foot of grate can be burned on an average from 10 to 15 pounds of hard coal, or 18 to 20 pounds soft coal, per hour, with natural draft. With forced draft nearly double these amounts can be burned.

Steam engines, in economy, vary from 14 to 60 pounds of feed water and from 1½ to 7 pounds of coal per hour per H. P.

Condensing engines require from 20 to 30 gallons of water, at an average low temperature to condense the steam represented by every gallon of water evaporated in the boilers supplying engines—approximately for most engines, we say, from 1 to 1½ gallons condensing water per minute per indicated horse-power.

Surface condensers should have about two square feet of tube (cooling) surface per horse-power for a compound steam engine. Ordinary engines will require more surface according to their economy in the use of steam. It is absolutely necessary to place air pumps below condensers to get satisfactory results.

Condensation discharged from steam traps and heaters into the atmosphere, when under pressures varying from 1 to 160 pounds, passes off 1 to 17 per cent of its volume in the form of vapor. This vapor must not be confounded with steam, as steam escaping through a partially opened valve is detected by a hissing sound.

WATER

A gallon of water (U. S. Standard) weighs 8⅓ pounds and contains 231 cubic inches.

A cubic foot of water weighs 62½ pounds, and contains 1,728 cubic inches, or 7½ gallons.

Doubling the diameter of a pipe increases its capacity four times.

The mean pressure of the atmosphere is usually estimated at 14.7 pounds per square inch, so that with a perfect vacuum it will sustain a column of mercury 29.9 inches, or a column of water 33.9 feet high at sea level.

To find the pressure in pounds per square inch of a column of water, multiply the height of the column in feet by .434. Approximately, we say that every foot elevation is equal to one-half pound pressure per square inch; this allows for ordinary friction.

To find the diameter of a pump cylinder to move a given quantity of water per minute (100 feet of piston being the standard of speed), divide the number of gallons by 4, then extract the square root, and the product will be the diameter in inches of the pump cylinder.

The area of the Steam Piston, multiplied by the steam pressure, gives the total amount of pressure that can be exerted. *The area of the water piston*, multiplied by the pressure of water per square inch. gives the resistance. *A margin* must be made between the *power* and the *resistance* to *move* (the pistons at the required speed), say from 20 to 40 per cent, according to speed and other conditions.

To find the capacity of a cylinder in gallons. Multiplying the area in inches by the length of stroke in inches will give the total number of cubic inches; divide this amount by 231 (which is the cubical contents of a U. S. gallon in inches), and product is the capacity in gallons.

THE STEAM ENGINE

The term horse-power is the standard measure of power as applied to steam engines. This unit of power has been adopted by all manufacturers of steam engines in all parts of the world.

The term originated with Watts, the so-called inventor of the steam engine. He demonstrated that a horse could work eight hours a day, continuously traveling at the rate of 2½ miles an hour raising a weight of 150 pounds 100 feet high by means of a block and tackle. Reducing this to equivalent terms, a horse could raise 150 pounds at the rate of 220 feet, per minute, or 2½ miles an hour, or 33,000 pounds one foot per minute. Thus a horse power is the power required to raise 33,000 pounds one foot a minute. There are three kinds of horse-power referred to in connection with engines—*Nominal*, *Indicated* and *Actual*.

The nominal horse-power is found by multiplying the area of the piston in inches by the average pressure, and multiplying this product by the number of feet the piston travels in feet per minute, then dividing this last product by 33,000, the quotient will be the nominal horse-power of the engine.

The indicated horse-power is found by multiplying together the mean effective pressure in the cylinder in pounds per square inch. The area of the piston in square inches and the sped of the piston in feet, per minute, and dividing the product by 33.000.

The actual horse-power is the indicated horse-power, minus the amount expended in overcoming the friction. The following is a general rule for calculating the horse-power of an engine:

Rule—Multiply the area of the piston in square inches, the mean pressure of the steam on the piston per square inch and the velocity of the piston in feet per minute together, and divide this product by 33,000, the quotient will be the horse-power.

The mean pressure in the cylinder less the friction in the pipes, when cutting off at—

¼ stroke, equals boiler pressure..... × .597.
⅓ stroke, equals boiler pressure..... × .670.
⅜ stroke, equals boiler pressure..... × .743.
½ stroke, equals boiler pressure..... × .847.
⅝ stroke, equals boiler pressure..... × .919.
⅔ stroke, equals boiler pressure..... × .937.
¾ stroke, equals boiler pressure..... × .966.
⅞ stroke, equals boiler pressure..... × .992.

To find the diameter of a cylinder of any engine of a required nominal horse-power:

Rule—Divide 5,500 by the velocity of the piston in feet per minute, and multiply the quotient by the required horse-power, the product will be the area of piston in square inches; from this the diameter can be obtained by referring to table of areas of circles.

To determine the effective power of an engine by an indicator:

Rule—Multiply the area of the piston in square inches by the average force of the steam in pounds; multiply this product by the velocity of the piston in feet per minute; divide this last product by 33,000, and 7-10 of the quotient will be the effective power. The travel in feet of a piston is found by multiplying the distance it travels in inches per one stroke by the whole number of strokes per minute; dividing this product by 12 gives the number of feet the piston travels per minute.

STEAM HEATING

In low pressure gravity systems of heating 85 square feet of radiating surface is equivalent to one horse-power. In vacuum systems at atmosphere or under from 90 to 100 square feet is equivalent to one horse-power. For all ordinary conditions of steam heating, to ascertain the proper size pipe to be used for a certain amount of radiation, the following rule will apply:

Take 1-10 the square root of the total radiation in square feet and the quotient is the diameter of pipe in inches.

To find the diameter of pipe required having given the H. P. of steam required, multiply the square root of horse-power by .408.

Pipe equivalent to one square foot radiation in one inch pipe is approximately 2.9 lineal feet.

MENSURATION

The area of a parallelogram. Multiply the length by the height or perpendicular by the breadth. Multiply the product of two contiguous sides by the natural sine of the included angle.

The area of a triangle. Multiply the base by the perpendicular height and take half the product. Multiply half the product of two contiguous sides by the natural sine of the included angle.

The area of a trapezoid. Multiply half the sum of the parellel sides by the perpendicular distance between them.

The area of any quadrilateral figure. Divide the quadrilateral into two triangles; the sum of the areas of the triangles is the area.

The area of any polygon. Divide the polygon into triangles and take the sum of their areas.

The circumference of a circle. Multiply the diameter by $3.1416 = .\eta$ reciprocal of η.

The area of a circle. Multiply the square of the diameter by .7854, or the circumference by one-fourth of the diameter.

The length of an arc of a circle. Multiply the number of degrees in the arc by the radius, and by .01745.

NOTE. — The length of an arc of one degree = radius × .017453
" " " " " " " minute = " × .000291
" " " " " " " second = " × 000005

The area of a sector of a circle. Multiply the length of the arc of the sector by half the radius.

The area of a segment of a circle. From the area of a sector substract the area of the triangle formed by the radial sides of the sector and its chord. The area of this triangle is the product of the natural sine and cosine by the square of the radial side.

The area of regular polygons. Find the area of one triangle, and multiply by the number of triangles composing the polygon:

Or, multiply the total cosines for the perphery by one-half the sine, by the square of the radius for the area.

	One-half Chord		No. of Sides		Vertical		Prod.
Pentagon	5878	×	5	×	.8090	=	2.3776
Hexagon	5000	×	6	×	.8660	=	2.5980
Heptagon	4357	×	7	×	.9032	=	2.7478
Octagon.	3827	×	8	×	.9238	=	2.8284
Nonagon	3420	×	9	×	.9396	=	2 8925
Decagon.....	3090	×	10	×	.9510	=	2.9389
Undecagon	2817	×	11	×	.9594	=	2.9739
Dodecagon	2588	×	12	×	.9660	=	3.0000
Circle.....	.....				.η	=	3.1416

To find—

The area of the cycloid. Multiply the area of the generating circle by 3.

To find—

The area of the parabola. Multiply the base by the height; two-thirds of the product is the area.

The circumference of an ellipse. Multiply the square root of half the sum of the squares of the two axes by 3.1416.

The area of an ellipse. Multiply the product of the two axes by .7854 = $\frac{1}{4}\ \eta$.

NOTE.—The area of an ellipse is equal to the area of a circle of which the diameter is a mean proportional between the two axes.

To find the area of any curvillineal figure, bounded at the ends by parallel straight lines. Divide the length of the figure into any number of equal parts and draw ordinates through the points of division, to touch the boundary lines. Or, add together the first and last ordinates, making the sum A; and add together all the intermediate ordinates, making the sum B. Let L. the length of the figure, and n = the number of divisions, then

$$\frac{A + 2B}{2n} \times L = \text{area of figure.}$$

That is to say, twice the sum of the intermediate ordinates, plus the first and last ordinates, divided by twice the number of divisions, and multiplied by the length, is equal to the area of the figure. This method is sufficiently exact for most purposes.

To find the surface of a prism or cylinder. To the product of th perimeter of the end by the height, add twice the area of an end.

The cubic contents of a prism or a cylinder. Multiply the area o the base by the height.

The surface of a pyramid or cone. Multiply the perimeter of th base by half the slant height, and add the area of the base.

The cubic contents of a pyramid or cone. Multiply the area of th base by one-third of the perpendicular height.

The surface of a frustum of a pyramid or a cone. Multiply th sum of the perimeters of the ends by half the slant height, and add th areas of the ends.

The cubic contents of the frustum of a pyramid or cone. Add to gether the areas of the two ends and the mean proportional betwee them (that is, the square root of their product) and multiply the sum b one-third of the perpendicular height.

The cubic contents of a wedge. To twice the length of the base ad the length of the edge; multiply he sum by the breadth of the base, an by one-sixth of the height.

The cubic contents of a prismoid (a solid of which the two ends ar unequal but parallel plane figures of the same number of sides). T the sum of the area of the two ends add four times the area of a sectio parallel to and equally distant from both ends; and multiply the sum by one-sixth of the length.

The surface of a sphere. Multiply the square of the diameter b 3.1416.

The surface of a sphere is equal to four times the area of one of it great circles.

The surface of a sphere is equal to the convex surface of its circum scribing cylinder.

The surfaces of spheres are to one another as the squares of thei diameters.

The curve surface of any segment or zone of a sphere. Multiply th diameter of the sphere by the height of the zone or segment, and b 3 1416.

The cubic contents of a sphere. Multiply the cube of the diamete by .5236 = $\frac{1}{6}\ \eta$.

The cubic contents of the segments of a sphere. From three time the diameter of the sphere subtract twice the height of the segment multiply the difference by the square of the height and by .5236.

The cubic contents of a frustum or zone of a sphere. To the sum o the squares of the radii of the ends add $\frac{1}{3}$ of the square of the height multiply the sum by the height and by 1.5708 = $\frac{1}{2}\ \eta$.

The cubic contents of a spheroid. (A solid body generated by th revolution of an ellipse around one of its axes). Multiply the square o the revolving axis by the fixed axis and by .5236.

ELECTRICAL UNITS

Unit of space: 1 centimetre, C; of mass, 1 gramme, G; of time, second, S.

The definitions of units as adopted at the International Electrical Congress at Chicago in 1893, established by Act of Congress of the United States, July 12, 1894, are as follows:

The ohm (the unit of resistance, represented by R.) is equal to 10^9 (or 1,000,000,000) units of resistance of C. G. S. system and is represented by the resistance offered to an unvarying electrical current by a column of mercury at 32° Fahr. (14 4521 grammes in mass) of a constant cross-sectional area, and of the length of 106.3 centimetres.

The ampere (the unit of current strength, or rate of flow, represented by C) is one-tenth of the unit of current of the C. G. S. system, and is the equivalent of the unvarying current which, when passed through a solution of nitrate of silver in water in accordance with standard specifications, deposits silver at the rate of .001118 gramme per second.

The volt (the unit of electro-motive force, or difference of potential, represented by E) is the electro-motive force that, steadily applied to a conductor whose resistance is 1 ohm, will produce a current of one ampere, and is equivalent to 1000/1434 (or .6794) of the electro-motive force between the poles or electrodes of a Clark's cell at a temperature of 15° C., and prepared in the manner described in the standard specications.

The coulomb (or ampere-second, the unit of Quantity, Q) is the quantity of electricity transferred by a current of one ampere in one second.

The farad (the unit of capacity represented by K) is the capacity of a condenser charged to a potential of one volt by one coulomb of electricity.

The joule (volt-coulomb, the unit of energy or work, W) is equal to 10,000,000 units of work in the C. G. S. system, and is practically equivalent to the energy expended in one second by an ampere in one ohm.

The watt, or ampere-volt (the unit of power, P) is equal to 10,000,000 units of power in the C. G. S. system and is practically equivalent to the work done at the rate of one joule per second; 746 watts = 1 H. P.

The henry (the unii of induction) is the induction in a circuit when the electro-motive force induced in this circuit is one volt, while the inducing current varies at the rate of one ampere per second.

The ohm, volt, etc. as above defined, are called "the international" ohm, volt, etc. to distinguish them from the "legal" ohm, B. A. unit, etc.

The value of the ohm, determined by a committee of the British Association in 1863, called the B. A. unit, was the resistance of a certain piece of copper wire preserved in London. The so-called "legal" ohm as adopted by the International Congress of Electricians in Paris in 1884, was a correction of the B. A. unit, and was defined as the resistance of a column of mercury 1 square millimetre in section and 106 centimetres long, at a temperature of 32° F.

1 legal ohm	= 1.0112 B. A. units,	1 B. A. unit	= 0.9889 legal ohm
1 international ohm	= 1.0136 " "	1 " "	= 0.9866 Int. ohm
1 " "	= 1.0023 legal ohm,	1 legal ohm	= 0.9977 " "

UNIT OF HEAT

The British Thermal Unit (B. T. U.) is that quantity of heat required to raise the temperature of 1 pound of pure water 1° F. at or near 39.1° F., the maximum density of water.

The French thermal unit, or calorie, is that quantity of heat which is required to raise the temperature of 1 kilogramme of pure water 1°C., at or about 4°C., which is equivalent to 39.1° F.

1 French calorie = 3.968 British thermal units, 1 B. T. U. = .252 calorie.

OFFICERS, 1904
American Public Works Association

PRESIDENT
J. A. OMBERG, JR., C E.,
Memphis, Tenn.

VICE-PRESIDENT
RICHARD C. HUSTON, C. E.
Laurel, Miss.

SECRETARY
W. H. FLINT
U. S. Cast Iron, Pipe & Foundry Co.
Chattanooga, Tenn.

TREASURER
H. J. MALOCHEE
Glenny & Castanedo
New Orleans, La.

RULES

of the American Public Works Association

1. When State or municipal statutes conflict with Association Rules, the latter shall be waived.
2. When work is done on a percentage basis, security should be given, to guarantee estimate and faithful performance of the work.
3. Designing engineer shall not compete for work advertised to be let under his plans and specifications.
4. No bids shall be asked until money to pay for the work has been provided.
5. Bids shall be opened and read in public.
6. No bids shall be submitted after time named in advertisement.
7. No bids shall be withdrawn after time set for opening of bids.
8. Illegibility or ambiguity shall invalidate a bid.
9. Bidders shall not be permitted to change prices stated in bid.
10. Bids shall state specifically make of apparatus or machinery proposed, and same shall be specified in contract.
11. When all bids are rejected, new bids shall not be made on the same specifications without re-advertising.
12. The amount of certified check required shall be stated in advertisement calling for bids.
13. Bid bonds may be substituted for certified checks.
14. Checks or bid bonds shall be returned to all but successful bidder as soon as award of contract is made.
15. Award of contract shall be made within thirty days after bids have been opened or checks returned to bidders.
16. Bonds shall not exceed twenty-five per cent of contract price.
17. Twenty days shall be allowed contractor in which to funish a satisfactory bond.
18. In event of discrepancies between the drawings and specifications, dicision of the engineer shall be final.
19. All instructions regarding work shall be given by the engineer.
20. Extra work shall only be done on written order of engineer, when authorized by contractee, at a price to be agreed upon.
21. In deducting material not required, only the value of same shall be deducted.
22. Changes in construction shall not be made to lessen quantities of material, in transit or in progress of manufacture, unless contractor be paid for all actual loss occasioned.
23. When a specific make of machinery or apparatus is specified in contract, same shall be furnished in accordance with manufacturer's plans and specifications, submitted with bid.

24. Engineer or his authorized assistants shall at all times have access to the work and materials, for purpose of inspection, and have notice of concealed work before it is covered.

25. In event of emergency work, contractor shall notify engineer, and engineer shall furnish inspector.

26. When work done in regular progress of the contract and ordered torn down for purpose of inspection, if found to be in accordance with the spec fications, shall be at cost of contractee.

27. Engineer shall give written notice to contractor when work or material has been rejected.

28. Monthly estimate shall be based on the contract price, and shall include all material delivered and labor performed during previous month.

29. Monthly estimate shall be made on or before the fifth day of each month.

30. Ten per cent of monthly estimate shall be retained by contractee until work is completed.

31. Time shall be allowed contractor for delay caused by strikes, accidents or other causes beyond his control.

32. When work is completed, engineer shall accept or reject same within a reasonable time.

33. Contractor is released from all future responsibility when contractee takes possession of plant, whether settlement has been made or not, unless otherwise agreed.

34. When work is accepted, ten per cent retained shall be paid in final settlement, and bond shall be released and returned, except where a time guarantee has been agreed upon.

35. Arbitration shall be resorted to in all cases before applying to the courts.

NOTE. In drawing specifications, if engineers will insert, "Work to be done under rules of American Public Works Association," it will not be necessary to print rules in full in specifications.

INDEX TO ADVERTISERS

The Engineering Record 40
Riter-Conley Mfg. Co. 41
The Acme Water Storage and Construction Co. 42
W. M. Money & Co. 43
Edward J. O'Beirne 44
J. P. Greenwood, M. E. 44
Engineering News 45
The American Well Works 46
The Platt Iron Works Co. 47
Chapman Valve Mfg Co. 48
The William C. Porter Construction Co. 49
Engineering News 50
Rensselaer Mfg. Co. 51
Chicago Bridge and Iron Works 52
The Walsh and Weidner Boiler Co. 53
The Brownell Company 54
The Bourbon Copper and Brass Works Co. 55
St. Louis Expanded Metal Fireproofing Co. 56
General Electric Co. 57
Eugene Deitzgen Co. 57
Southern Sewer Pipe Co. 58
Gardner Governor Co. 59
Rudolph Kleybolte Co. 60
Edison Mfg. Co. 61
Herron Pumps and Foundry Co. 62
Crocker-Wheeler Co. 63
Work of R. C. Huston, C. E. 64

Save Money on your *Contract Work* by Advertising it in THE ENGINEERING RECORD

The foremost contracting news journal and recognized medium for such advertising.

It reaches more responsible contractors than any other publication in America.

In its columns, a proposal advertisement will be brought to the attention of all likely bidders.

Cities, Counties, States, the United States Government, and many private institutions and companies, recognize it as the BEST MEDIUM in which to advertise their contracts.

If you plan any improvement or construction work, close competition may be had by placing a small advertisement in its columns.

Rates, $2 40 per inch per issue. Sample copies for postal.

THE ENGINEERING RECORD

114 LIBERTY ST. , , , , , NEW YORK

THOS. B. RITER.
President.

JNO. S. CRAIG,
Sec'y and Treas.

WM. C. COFFIN,
Vice President.

ROBT. A. McKEAN.
General Manager.

RITER-CONLEY MFG. CO.

PITTSBURGH, PA.

Steel Construction the World Over

Engineers, Designers & Contractors

Stand Pipes ✕ Gas Holders
Water Tanks ✕ Gas Works
Oil and Gas Tanks
Iron Mill and Factory Buildings
Power Plants Riveted Steel Pipe
Cold Storage and Ash Tanks

General Offices, . . . 55 and 56 Water Street, Pittsburgh, Pa.
New York Office, ... 39 and 41 Cortland Street
Plate Works, ... Leetsdale, Pa.
Structural Works, ... Allegheny City, Pa.
CAPACITY, ... 100,000 TONS ANNUALLY

The Acme System of Water Storage

Takes the Place of Stand Pipes, Elevated and Overhead Tanks

Delivers every gallon of water, stored in the tanks, at an unvarying pressure with the pumping machinery at complete rest.

Needs no attention after the tanks are charged.

Designed for the water supply to towns, country residences and establishments, and to tall buildings.

Specially adapted to operate automatic sprinklers and other fire-fighting devices which require a constant high pressure.

The tanks being air-tight, the water is absolutely beyond contamination after it has been stored.

As the tanks can readily be sheltered from the sun's rays the water is kept cool.

The storage capacity of these plants can be increased without disturbing any part of the original installation, making the system a most economical one for growing towns.

Adopted by the United States Government in its fortifications.

Endorsed by the National Board of Fire Underwriters.

THE ACME WATER STORAGE & CONSTRUCTION CO.

PARK ROW BLDG. NEW YORK, N. Y.

W. M. MONEY & CO.

Well Contractors

LAUREL, MISSISSIPPI

Contracts for Artesian Wells,
Oil Wells, etc.

Specifications and Estimates
Furnished on Application.

Estimates Furnished and
Contracts Taken for All
Kinds of Pumping Plants.

MEMBER

AMERICAN PUBLIC WORKS ASSOCIATION

EDWARD J. O'BEIRNE

Contracting Engineer

MEMBER AMERICAN PUBLIC WORKS ASSOCIATION

Electric Light Plants

Railway Construction

Water Works and Sewerage

418 SCIMITAR BUILDING, MEMPHIS, TENN.

Plans, Specifications and Estimates Furnished for Complete Electric Plants & Electric Light and Power Installations Superintended.

J. P. GREENWOOD, M. E.

MEMBER AMERICAN PUBLIC WORKS ASSOCIATION

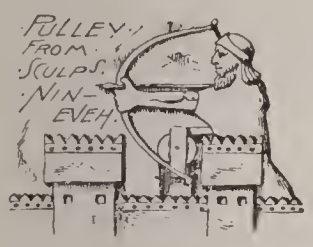
Consulting and Contracting Engineer

Representing

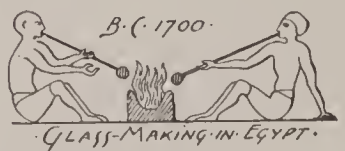
Electric Machinery Co., Minneapolis, Minn.
Reeves Engine Company, New York City
M. T Davidson (Pumps), Brooklyn
Tudor Boiler Manufacturing Company, Cincinnati

ROOM 918, HIBERNIA BUILDING, COR. CARONDELET AND GRAVIER STREETS
NEW ORLEANS, LA.

WORK WELL DONE



IS MONEY SAVED



ENGINEERING NEWS

has for over thirty years been used by all the leading cities, towns and counties in America when bids are wanted from responsible contractors and supply firms. . . . . The following from officials refer to work advertised in ENGINEERING NEWS:

"The work has been awarded at prices satisfactory to this Council."—J. F. G., Sec'y, Jersey Shore, Pa.

"Was a successful letting."—W. H. R., City Engineer, Columbus, Ind.

"I received forty-three applications in reply to our short ad. for water works and electric lights."—B. M., City Clerk, Canton, Miss.

"We have frequently recommended Engineering News as an advertising medium."—M. & S., Eng'rs Atlanta, Ga.

"We feel that the ad. for furniture and fixtures paid us." F. W. R., County Clerk, Fairfax, Va.

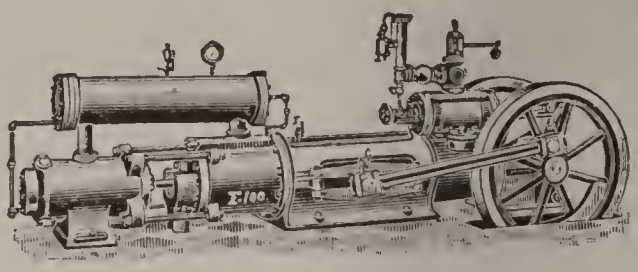
Rate for Proposal Advertising is $2.40 an inch a time. Send us details regarding proposed work in which you are interested. : :

SEND FOR A COPY TO DEPARTMENT E. H.-1

ENGINEERING NEWS

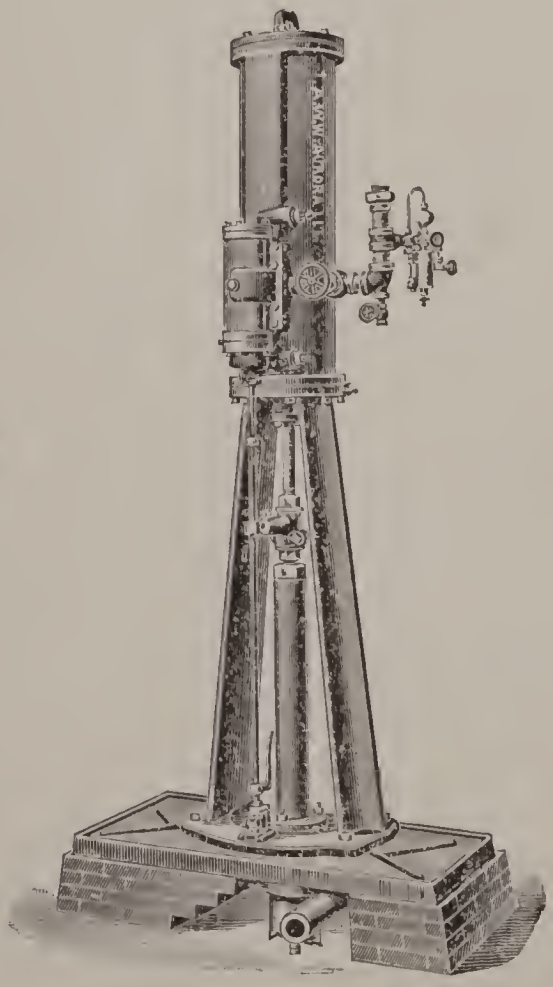
220 BROADWAY NEW YORK

The American Well Works, Aurora, Ill., U. S. A.



Manufacture THE

UP-TO-DATE VERTICAL DEEP-WELL PUMPING MACHINERY AND ACCESSORIES



Install Complete

CHAPMAN'S COMPRESSED AIR WATER LIFT SYSTEM PLANTS, COMPRESSORS, Etc., for Villages, Cities and Corporations ⁂ Driven by Steam, Electricity or Gasoline

Ask for our printed matter and send in your specifications

The Platt Iron Works Co. of Dayton, Ohio

SUCCESSORS TO

The Stilwell-Bierce & Smith-Vaile Co.

MANUFACTURERS OF

Pumping Machinery for Water Works Service; duplex, compound, triple expansion and crank and fly wheel types; condensing and non-condensing ✕ Duplex and Triplex Power Pumps ✕ Electric Pumps ✕ Gas Engine Pumps ✕ Centrifugal Pumps Sewage Pumps ✕ Condensing Apparatus ✕ Air Compressors for Air Lift Systems ✕ also the Stilwell Feed Water Heater and Purifier ✕ the Victor Turbine ✕ Smith-Vaile Oil Mill Machinery ✕ ✕ ✕ ✕

Principal Office: Dayton, Ohio.

Sales Houses at 304 Hennen Building, New Orleans, La.
411 Empire Building, Atlanta Ga,
and Dallas, Texas.

Chapman Valve Mf'g Company

MANUFACTURERS OF

Valves and Sluice Gates

Are prepared to furnish reliable information and estimates regarding Valves for Water Works, Sewerage Systems, Steam Power Plants, Lighting and Traction Stations and Fire Protection Systems. ∴ ∴ ∴

ELECTRICALLY OPERATED VALVES---FIRE HYDRANTS

Designed upon engineering principles and accurately constructed of the highest grade materials.

WE SOLICIT YOUR INQUIRIES.

GENERAL OFFICES AND WORKS:

Indian Orchard, Mass., U.S.A.

BRANCHES;

Boston, 94 Pearl Street.
Philadelphia, 18 N. Seventh Street.
Cleveland, 97 Superior Street.
San Francisco, 63 First Street.
New York, 28 Platt Street.
Chicago, 28 S. Canal Street.
St Louis, 618 Chemical Building.
Buffalo, 380 Ellicott Square.

THE

William C. Porter Construction Co.

LAUREL MISS.

CONSTRUCTING Engineers in the construction of Water Works, Sewers, Electric Lighting Plants, and other Municipal Improvements

WM. C. PORTER
PRESIDENT

CORRESPONDENCE SOLICITED

MEMBER AMERICAN PUBLIC WORKS ASSOCIATION

"More than 50 contractors and material men attended our water-works letting, advertised in the Engineering News. They were men of intelligence, well-informed, affable and good-natured, and everything passed off pleasantly. The prices were low and close."

—*R. L. M., Mayor, Cuthbert, Ga.*

IT is a pleasure to do business with such contractors and engineers. These are the men who read

ENGINEERING NEWS

Construction work and the supplies for such will cost less if the advertisement calling for bids is ordered inserted in this journal. THE RATE IS ONLY $2.40 AN INCH. : : : : : : : :

DO YOU WANT HIGH-CLASS HELP?

If so, insert a small Situations Open Advertisement in Engineering News. THE RATE IS ONLY 3 CENTS A WORD.

BOOKS ON MUNICIPAL ENGINEERING

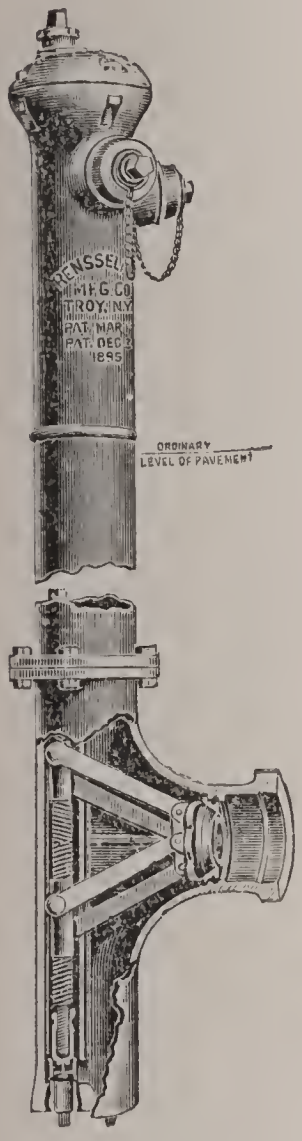
Are for sale by us. Mayors, Councilmen and Commissioners should keep posted on subjects interesting them by reading the latest works. Send for Catalogue '04.

ENGINEERING NEWS, 220 Broadway, New York.

THE GREAT QUARRIED STONE AT BALBEC: (14'X16'X69')

Rensselaer Mfg. Co.

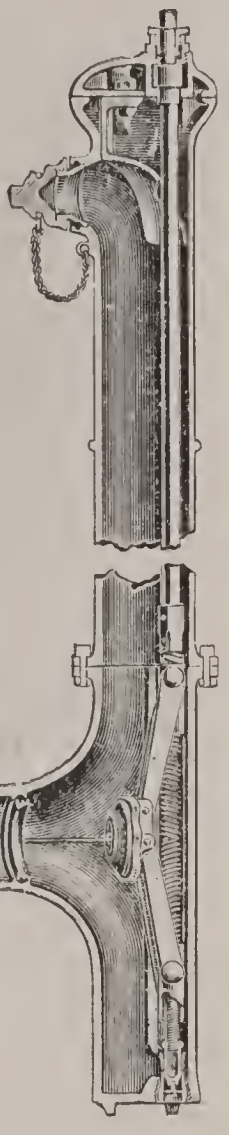
TROY, N. Y.



BRASS and IRON

GATE VALVES

For Water, Gas,
Steam or Oil.

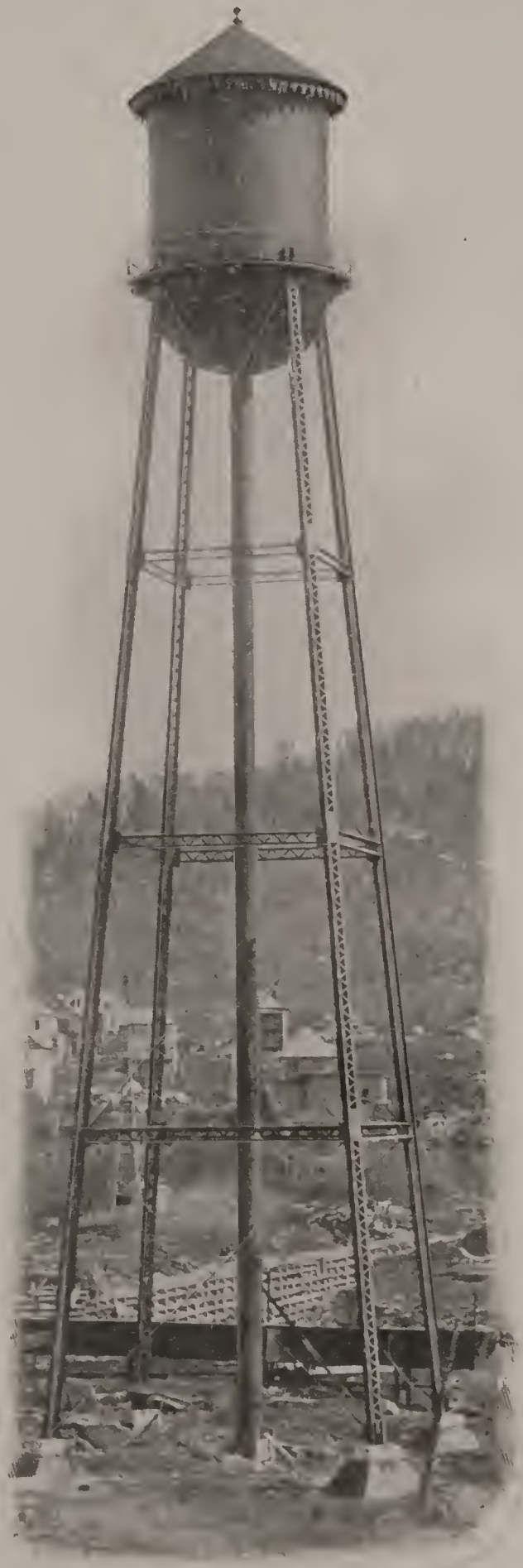


THE COREY

Fire Hydrant

ST. LOUIS OFFICE,

401 SECURITY BUILDING



THEY DO NOT LEAK

CHICAGO BRIDGE and IRON WORKS

HORACE E. HORTON

PROPRIETOR

1400-105th St., Chicago Ill.

Steel Water Towers and Stand Pipes

Cut shows one of our Standard WATER TOWERS for Municipal Service, of which we have designed and built more than one hundred in the Southern States.

WRITE FOR CATALOG

The Walsh & Weidner Boiler Co.

CHATTANOOGA, TENNESSEE,

Build

Towers and Tanks, Stand Pipes, Boilers of All Types,

x x x

STANDARD and HIGH PRESSURE TUBULAR
SCOTCH and CLYDE MARINE
WATER TUBE,

x x x

All Kinds of Plate and Sheet Iron Work Castings

x x x

WE CARRY IN STOCK A FULL LINE OF

Valves, Fittings, Pipe, Packing

The Brownell Company

DAYTON, : : : OHIO

PLAIN & AUTOMATIC

ENGINES

STEAM

BOILERS

FEED WATER

HEATERS

THOMAS FORD
President

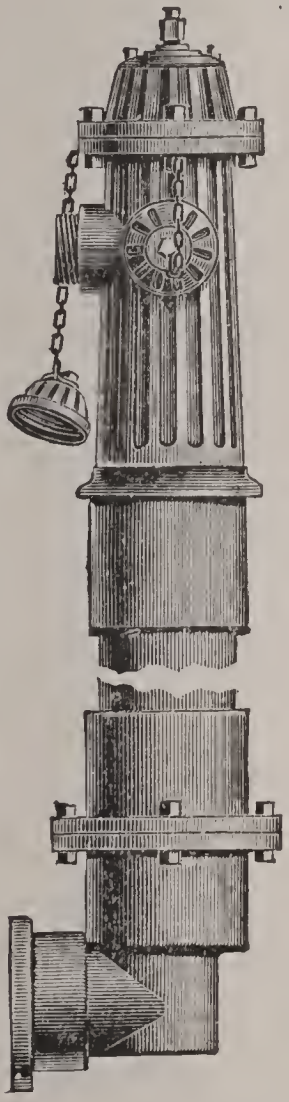
P. BARDO
Treasurer

THE BOURBON COPPER & BRASS WORKS CO

CINCINNATI : : OHIO

No. 618-620 East Front Street

Long Distance Phone
Main 1936



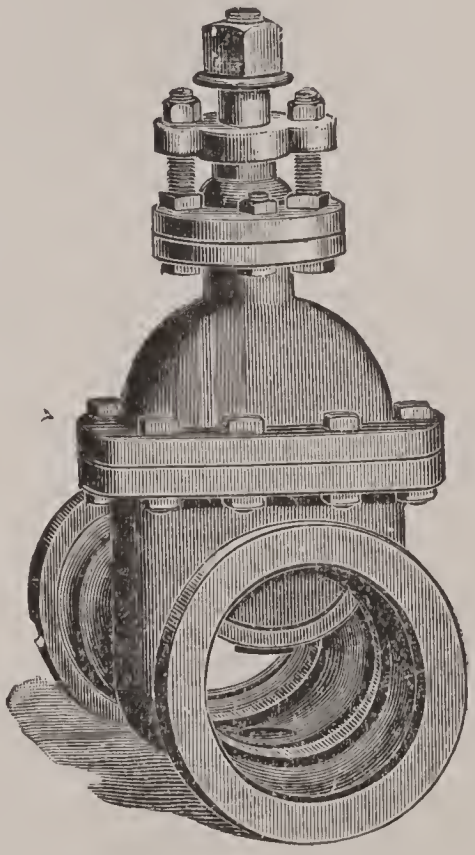
Manufacturers of

Fire Hydrants

Stop Valves

and

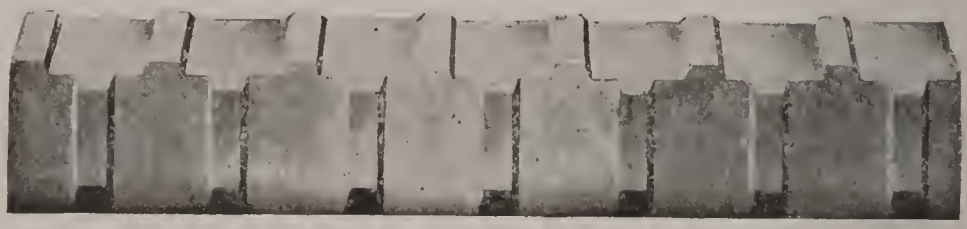
Extension Valve Boxes



ADHESION NOT NECESSARY WITH

CORRUGATED STEEL BARS

FOR STEEL CONCRETE CONSTRUCTION



½-in. Bar.	Net Section, 0.18 sq. in.	Weight, 0.64 lbs. per ft.
¾-in. Bar.	Net Section, 0.37 sq. in.	Weight, 1.35 lbs. per ft.
⅞-in. Bar.	Net Section, 0.55 sq. in.	Weight, 1.95 lbs. per ft.
1 -in. Bar.	Net Section, 0.70 sq. in.	Weight, 2.70 lbs. per ft.
1¼-in. Bar.	Net Section, 1.07 sq. in.	Weight, 4.00 lbs. per ft.

These bars have an elastic limit of between 50,000 and 60,000 lbs. per sq. inch.

Catalogues and designs furnished on application.

St. Louis Expanded Metal Fireproofing Co.

A. L. JOHNSON. (M. Am. Soc. C. E.) COMPANY ENGINEER.

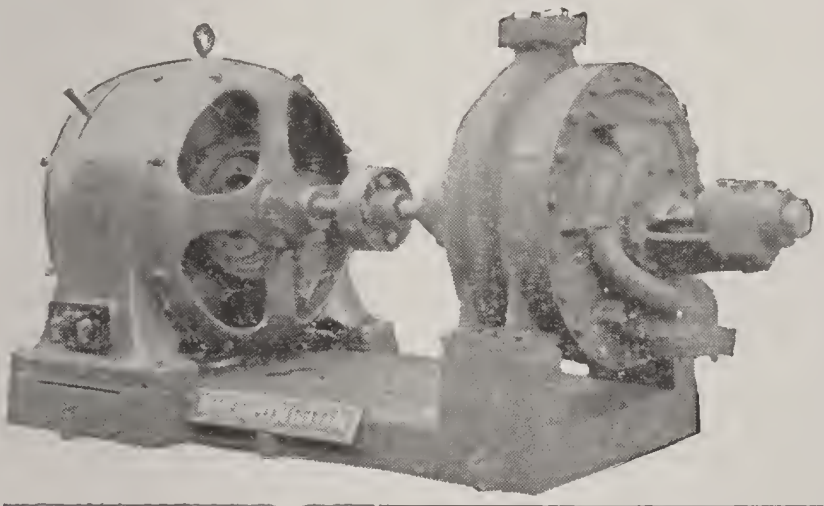
ST. LOUIS, U. S. A., General Agents

BRANCH AGENCIES:

H. C. Miller, M. Am. Soc. C. E., 1 Madison Ave., New York City.
Buffalo Expanded Metal Co., D. S. Morgan Building, Buffalo, N. Y.
T. L. Condron, M. Am. Soc. C. E., 1750 Monadnock Building, Chicago.
Walter L. Webb, M. Am. Soc. C. E., Philadelphia.
J. T. Norton, M. Am. Soc. C. E., 606 Commercial Place, New Orleans, La.

General Electric Co.

ELECTRICALLY DRIVEN TURBINE PUMPS



Two Stage Worthington Turbine Pumps driven by Direct Current General Electric Motor. Capacity, One Million Gallons every twenty-four hours up to 200 feet heads. :: :: ::

GENERAL OFFICE:

SCHENECTADY, N. Y.

Atlanta Office, Empire Building. Sales Offices in all Large Cities

EUGENE DIETZGEN COMPANY

NEW YORK CHICAGO NEW ORLEANS SAN FRANCISCO

WE DO

BLUE PRINTING

Send us your Tracings. Originators of the celebrated *VAN DYKE PROCESS* for making Black Prints. Fine and complete stock Drawing Materials and Surveying Instruments and all other goods used by the Architect, Engineer or Draftsman. 350 page Catalogue Free upon application,

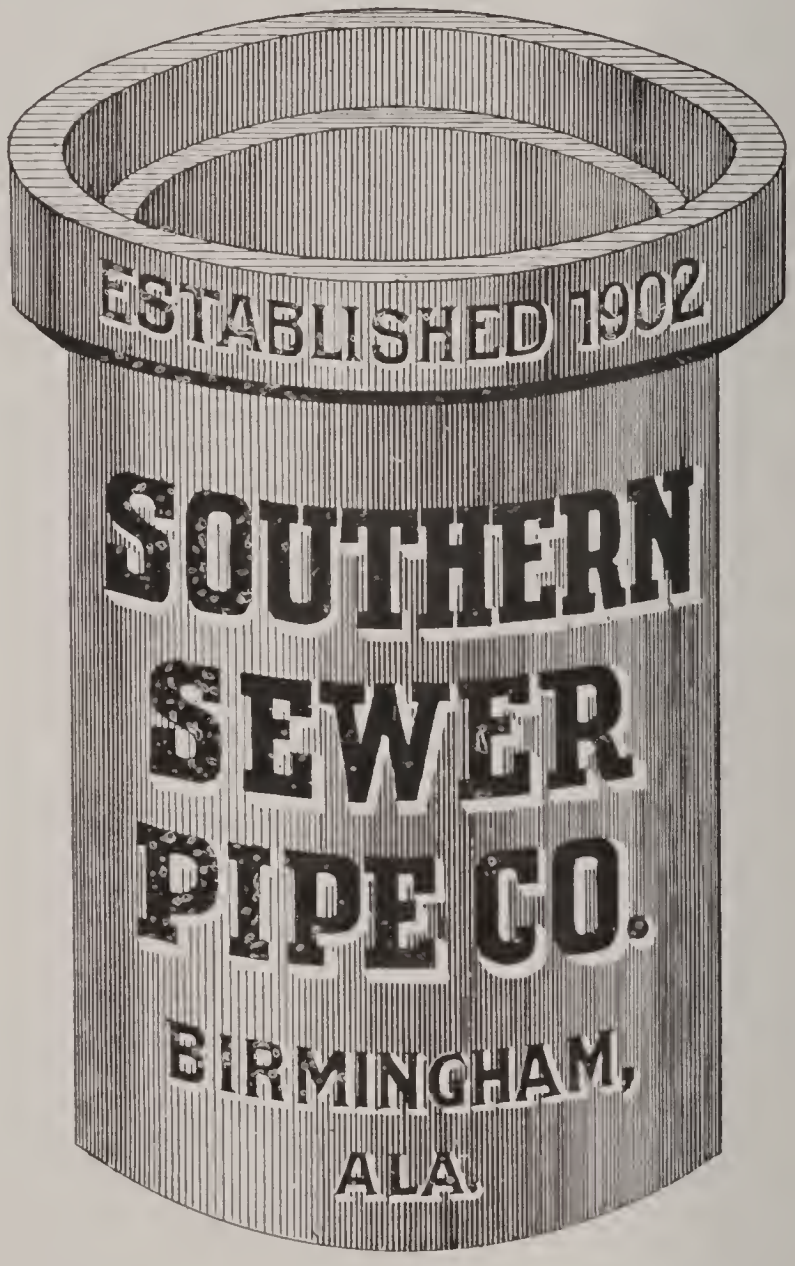
NEW ORLEANS BRANCH:

NO. 145 BARONNE STREET

NEW ORLEANS, LA.

Send for Our Catalogue

Manufacturers of High-Grade Vitrified Salt Glazed SEWER PIPE, Made from Shale.



Manufacturers of High-Grade Vitrified Salt Glazed SEWER PIPE, Made from Shale.

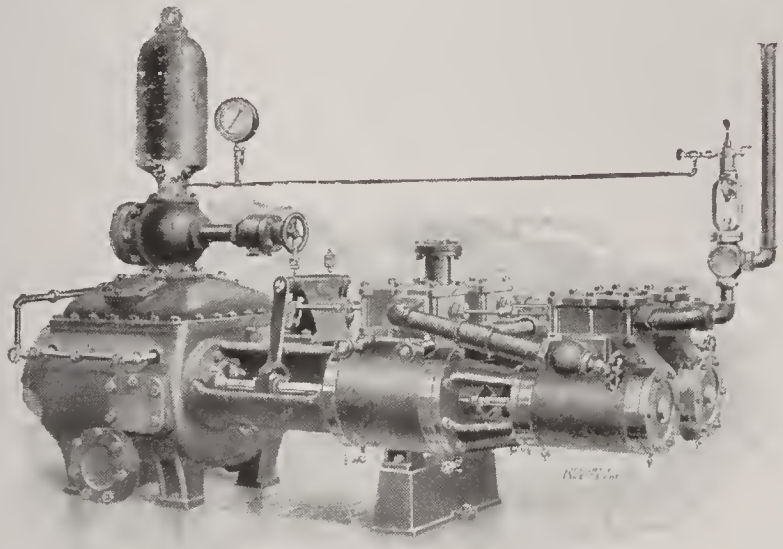
Large Discounts allowed.

Gardner Pumping Machinery

FOR WATER WORKS PURPOSES

Excel in Excellence of Construction

and General Reliability.



MADE IN SIMPLE AND COMPOUND TYPES FROM 200,000 TO 2,000,000 GALLON CAPACITIES. ALSO FULL LINE OF BOILER FEEDERS, TANK, FIRE AND ELEVATOR PUMPS.

CORRESPONDENCE FROM CITIES CONTEMPLATNIG WATER WORKS INSTALLATIONS SOLICITED : : :

THE GARDNER GOVERNOR CO.

QUINCY, ILLINOIS.

WE BUY OUTRIGHT

Total issues of

MUNICIPAL BONDS

Issued for *Water Works* and other *Public Improvements.*

Correspondence with Municipal Officers Solicited in Regard to Forthcoming Issues.

RUDOLPH KLEYBOLTE & CO.

First Nat. Bank Bld., Cincinnati.

1 Nassau St., New York.

171 LaSalle St., Chicago.

EDSON MNFG. CO'S.

DIAPHRACM TRENCH PUMPS

Will raise water containing sand, gravel, or sewage matter, or anything liquid enough to flow. They are made in two sizes:

No. 3, capacity 4,000 gallons per hour, one man
No. 4, capacity 6,000 gallons per hour, two men

No. 3	Pump,	with	15	ft.	of	Suction	Hose,	order	name,	RACHIDIEN,	Price, $52.50
No. 3	"	"	20	"	"	"	"	"	"	RACKRENT,	" 60.00
No. 4	"	"	15	"	"	"	"	"	"	RARENESS,	" 77.00
No. 4	"	"	20	"	"	"	"	"	"	RASHNESS,	" 88.25

Prices include Pump, Special Suction Hose, Brass Couplings, Strainer and Spanner, complete, ready for immediate use.

70,000 sold in fifteen years.

EDSON MANUFACTURING COMPANY
257 Atlantic Avenue BOSTON, MASS.

HERRON PUMP & FOUNDRY COMPANY

Pumping Machinery
for Every Service

Fire Hydrants
Gate Valves

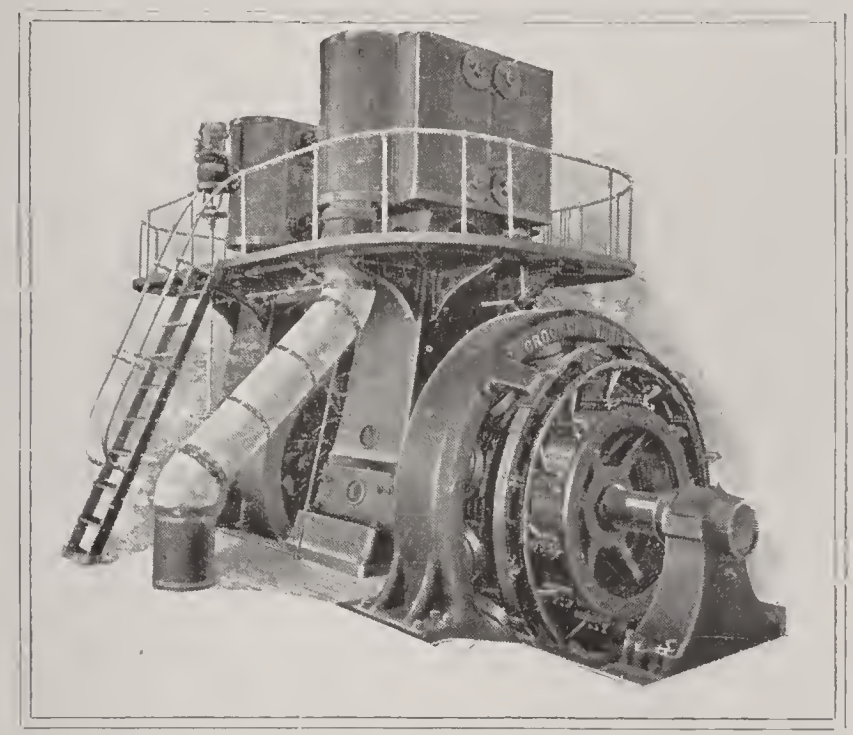
Brass Castings

Grey Iron Castings

CHATTANOOGA,
TENNESSEE

ELECTRIC GENERATORS

Alternating and Direct Current
FOR EVERY SERVICE



Crocker-Wheeler Direct Current Generator, driven by a Vertical Engine

WRITE OUR NEAREST OFFICE FOR
RECOMMENDATIONS

Crocker-Wheeler Company

MANUFACTURERS & ELECTRICAL ENGINEERS

Branch Offices in 15 cities--St. Louis, Chicago, Atlanta, Etc.

New Orleans Office
Hibernia Bank Building

AMPERE, N. J.

MAY 3 1905

Assistant Engineer to Colonel J. T. Foster, C. E., and Horace C. Alexander, C. E., of Chicago, on the following work:

La Grange, Ill. . . . . Sewer
Wilmette, Ill. . . . . Sewer and Water Works
West Pullman, Ill. . . . . Sewer and Water Works
Des Plaines, Ill. . . . . Sewer and Water Works
Maywood, Ill. . . . . Water Works
Rogers Park, Ill. . . . . Sewer and Street Work
Lake Forest, Ill. . . . . Sewer and Street Work

AGGREGATING $500,000

Designing and Supervising Engineer

Edison Park, Ill. . . . . Water Works and Sewer
South Haven, Mich. . . . . Water Works
South Wilmington, Ill. . . . . Water Works
Des Plaines, Ill. . . . . Water Works, Sewer and Street Work
Arlington Heights, Ill. . . . . Sewer and Street Work
Barrington, Ill. . . . . Consulting Engineer Water Works
Mount Olive, Miss. . . . . Designing Engineer Water Works
Poplarville, Miss. . . . . Designing Engineer Water Works
Indianola, Miss. . . . . Designing Engineer Water Works Reconstruction
Carrollton, Miss. . . . . Consulting Engineer Water Works
Laurel Improvement Co., Laurel Miss. . . . . Consulting Engineer
LaCrosse, Wis. . . . . Constructing Engineer Street Work
Morgan Park, Ill. . . . . Constructing Engineer Street Work
South Haven, Mich. . . . . Constructing Engineer Water Works
American Bridge Co., Chicago. . . . . Constructing Engineer Bridges

Consulting Engineer for Contractors on the following Public Improvements

City of Chicago. . . . . Sewers
Washington Heights, Ill. . . . . Sewers
Sault Ste. Marie, Canada . . . . . Power Canal
St. Louis. . . . . Storm Sewers
City of Chicago . . . . . Intake and Tunnel under Lake Michigan for Water Supply.

AGGREGATING $2,500,000

Examination and Reports

Beaumont, Texas. . . . . Water Works
Janesville, Wis. . . . . Water Works
Natchez, Miss. . . . . Street Railway and Electric Lights
Jackson, Miss. . . . . Street Railway and Electric Lights
Baton Rouge, La. . . . . Street Railway and Electric Lights
Laurel, Miss. . . . . Laurel Electric Light Plant

AGGREGATING $2,000,000

Acting County Surveyor, Cook County, Chicago, Ill.
Engineer and Surveyor for Board of Education, Chicago, Ill.

LB D '05

84 94

HECKMAN
BINDERY INC.
DEC 93
N. MANCHESTER,
INDIANA 46962

LIBRARY OF CONGRESS
0 027 304 175 8